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Revising EPA's nationally recommended numeric nutrient criteria for lakes and reservoirs

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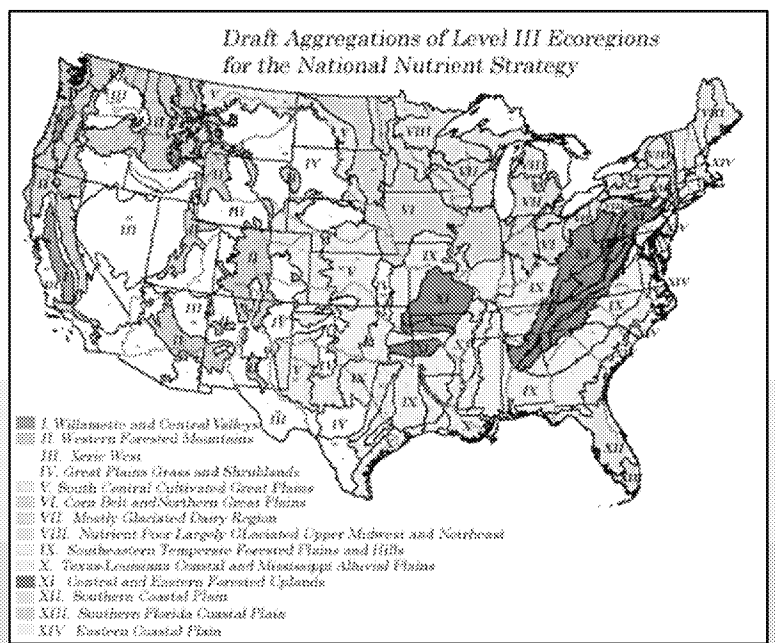
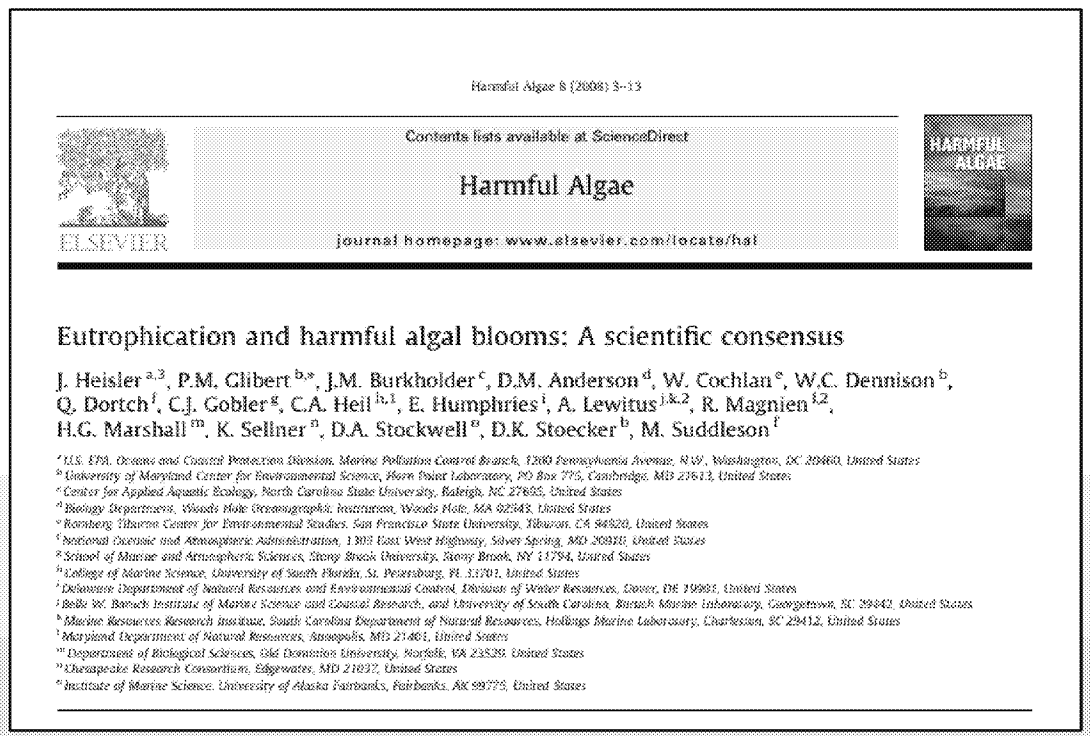
EPA's existing recommended nutrient criteria

- EPA published numeric nutrient criteria recommendations in 2000 – 2001 for lakes and reservoirs.
- U.S. classified into 14 nutrient ecoregions in which nutrient concentrations were expected to be similar.
- Criteria were derived using a reference distribution approach.
  - Numeric criterion values were the 25th percentile of all available total nitrogen (TN), total phosphorus (TP), chlorophyll *a* (chl *a*), and Secchi depth.
  - Data were sufficient to apply this approach in 12 of 14 ecoregions.
- Criticized for not linking directly to support of designated uses (aquatic life, recreation, and drinking water source).



Nutrients and harmful algal blooms

- Latest science documents linkages between an increased frequency of harmful algal blooms and increased nutrient concentrations.



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Eutrophication and harmful algal blooms: A scientific consensus

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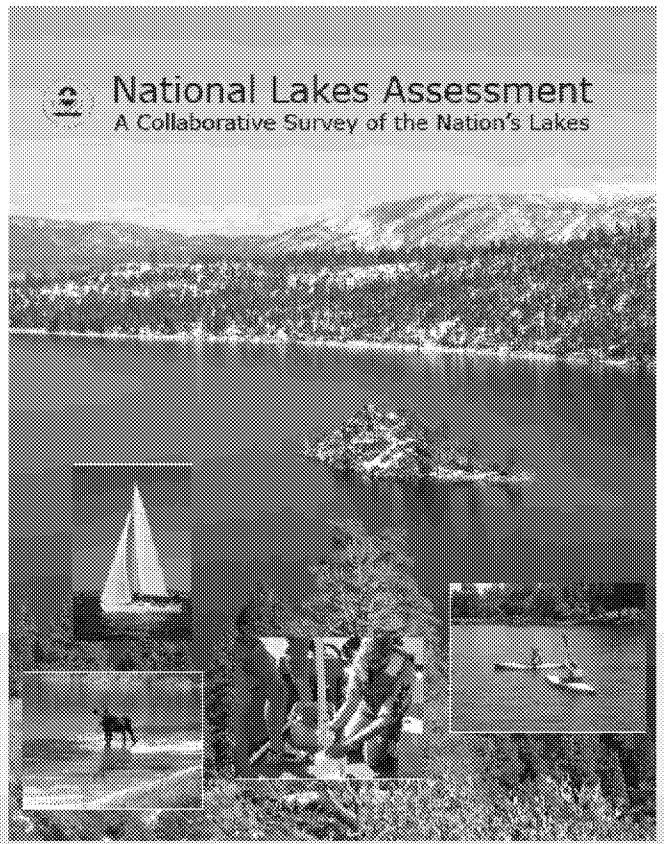
Nationally consistent data for lakes and reservoirs are now available

- Lakes assessment data from the EPA's National Aquatic Resource Surveys.
  - Survey data from 2007 and 2012 included.
  - Extensive set of measurements collected at ~ 1800 randomly selected lakes.
  - Consistent protocols used to collect the same measurements from each of the lakes.
  - Data available for the stressors (TN and TP) and the responses (i.e., chl *a*, dissolved oxygen, microcystin, and zooplankton biomass) allow EPA to derive criteria specifically to prevent adverse effects.



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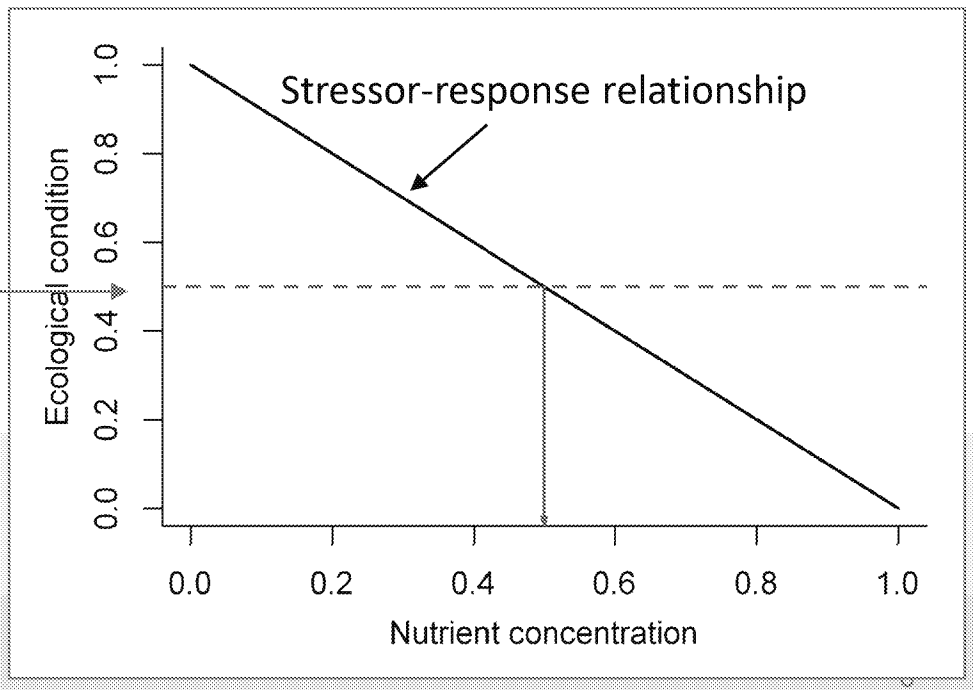
Benefits of updated recommended criteria

1. Stressor-response relationships are used to link chl *a* concentration to attainment of each of three designated uses (aquatic life, recreation, and drinking water source).
2. When multiple use designations apply to a lake, states and tribes can calculate and compare candidate criteria for each applicable use to inform their risk management decisions (40 CFR 131.11(a)).
3. Criteria development tools are based on stressor-response models and can combine state and national data to derive state-specific values that reflect local conditions.
4. Tools provide flexibility for each state to incorporate their own risk management decisions in deriving final criteria.

Stressor-response analysis: Step 1

Define the endpoint and threshold.

How do we quantify "ecological condition" and set an appropriate threshold?



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Defining assessment endpoints

- Characteristics of useful assessment endpoints:
  - Responsive to nutrients
  - Quantitative
  - Linked directly to management goal
  - Data available

- Water quality management goals based on state designated uses:
  - "…restore and maintain the chemical, physical, and biological integrity…"

  - Three designated uses that can be affected by nutrients
    - Aquatic life
    - Recreation
    - Drinking water source

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Defining assessment endpoints to protect aquatic life

- Water quality management goal:
  - State designated use related to the protection and propagation of fish, shellfish and wildlife

- Selecting different endpoints ensures that aquatic life in different types of lakes is protected.
  - Zooplankton
  - Fish

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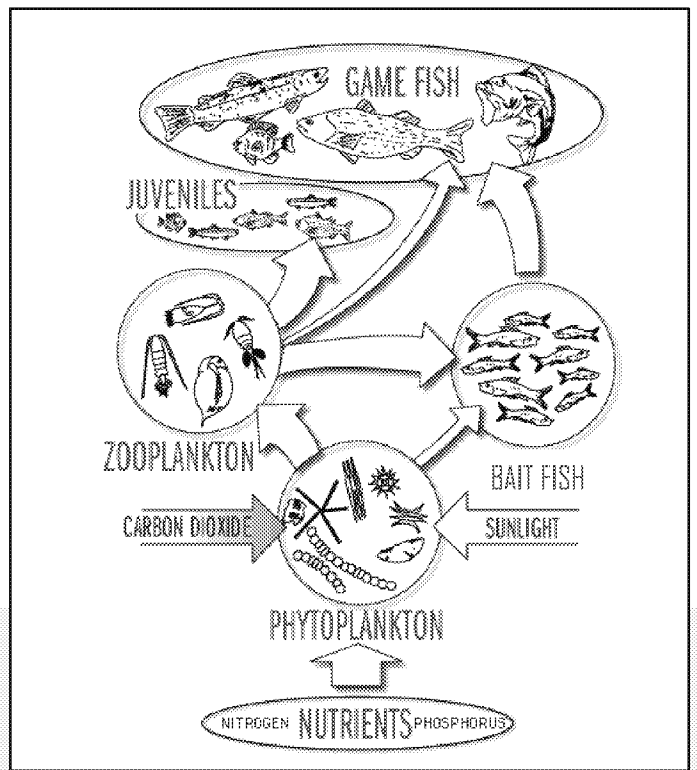
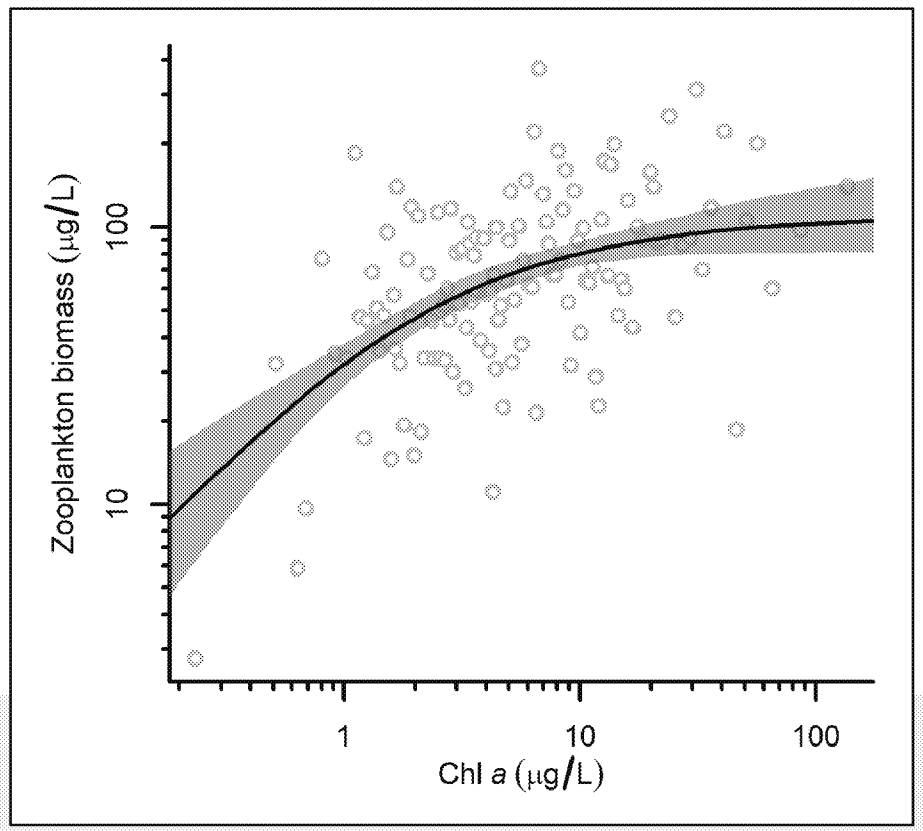
Aquatic life assessment endpoint: Zooplankton

- Key link in lake food web
- Concurrent increases in phytoplankton and zooplankton biomass are indicative of an efficient transfer of resources up the food web.



http://www.waterontheweb.org/under/lakeecology/11_foodweb.html

Aquatic life assessment endpoint: Zooplankton



In lakes with high concentrations of phytoplankton and nutrients, transfer of energy from primary productivity to higher trophic levels is less efficient.

When chlorophyll *a* exceeds ~ 30 µg/L, zooplankton biomass does not increase with phytoplankton.

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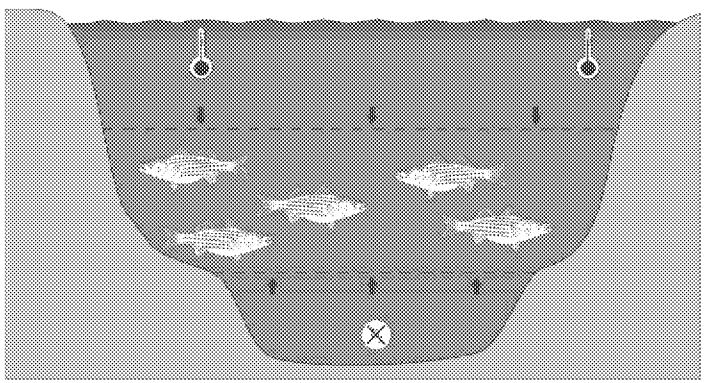
Aquatic life assessment endpoint: Fish

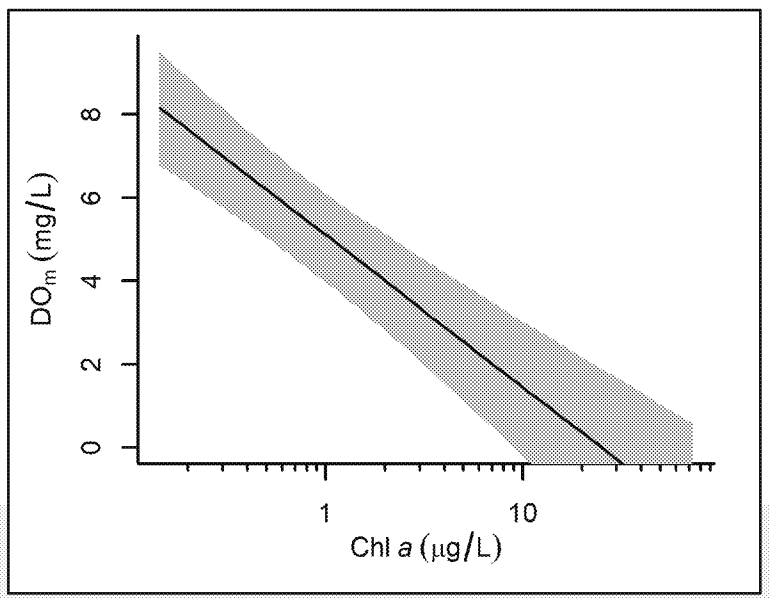
- Distribution of many fish species is limited by water temperature.
- In stratified lakes, depletion of oxygen in deep water below the thermocline can eliminate viable habitat for certain fish species.
- Potential endpoint: Sufficiently dissolved oxygen below thermocline to allow fish to persist through the summer (US EPA 1986).



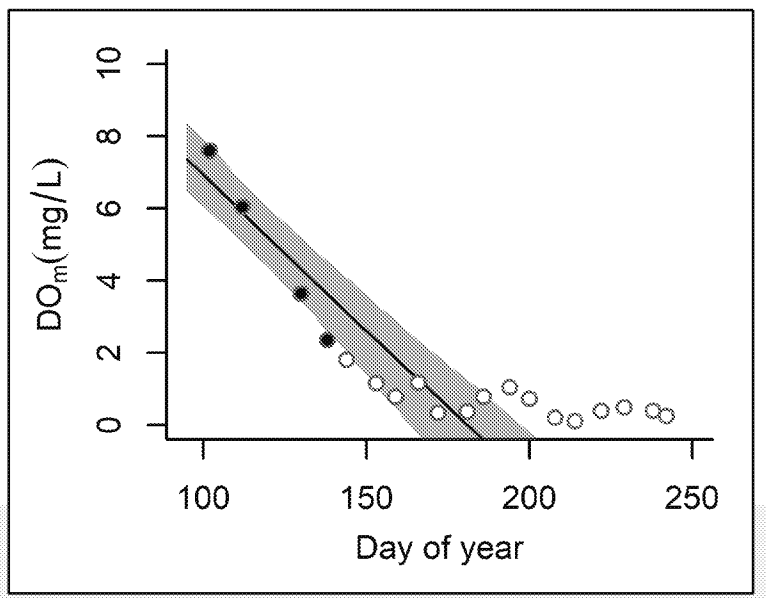
http://www.teachoceanscience.net/teaching_resources/education_modules/fish_and_physics/explore_trends/oxygen_and_water_temperature/

Chl *a* and dissolved oxygen

Depth-averaged dissolved oxygen (DO_m) decreases with increased Chl *a*.



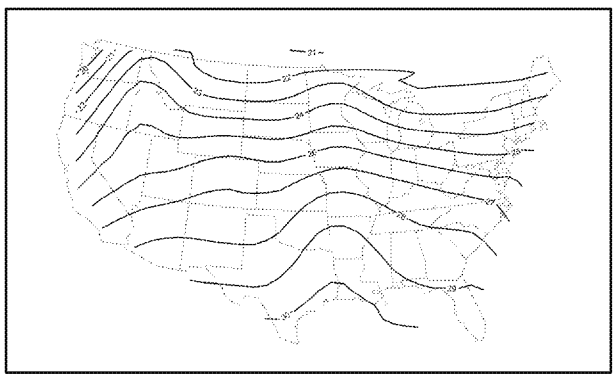
Number of days since stratification is also important.



Dissolved organic carbon and lake depth also influence DO_m.

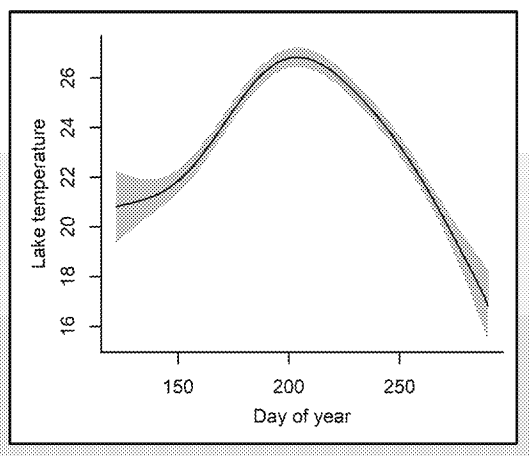
Lake temperature model

Location

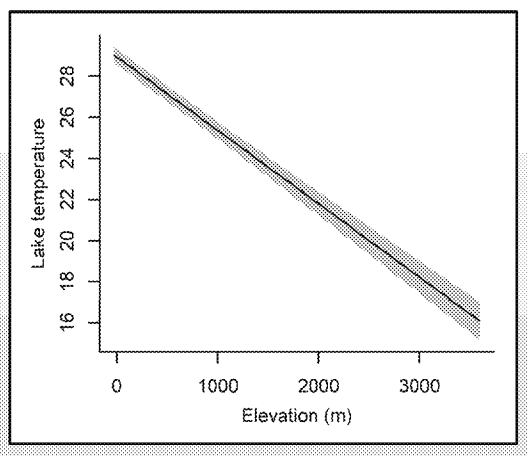


Lake surface temperature model varies with day of the year, elevation, and location.

Day of the year



Elevation



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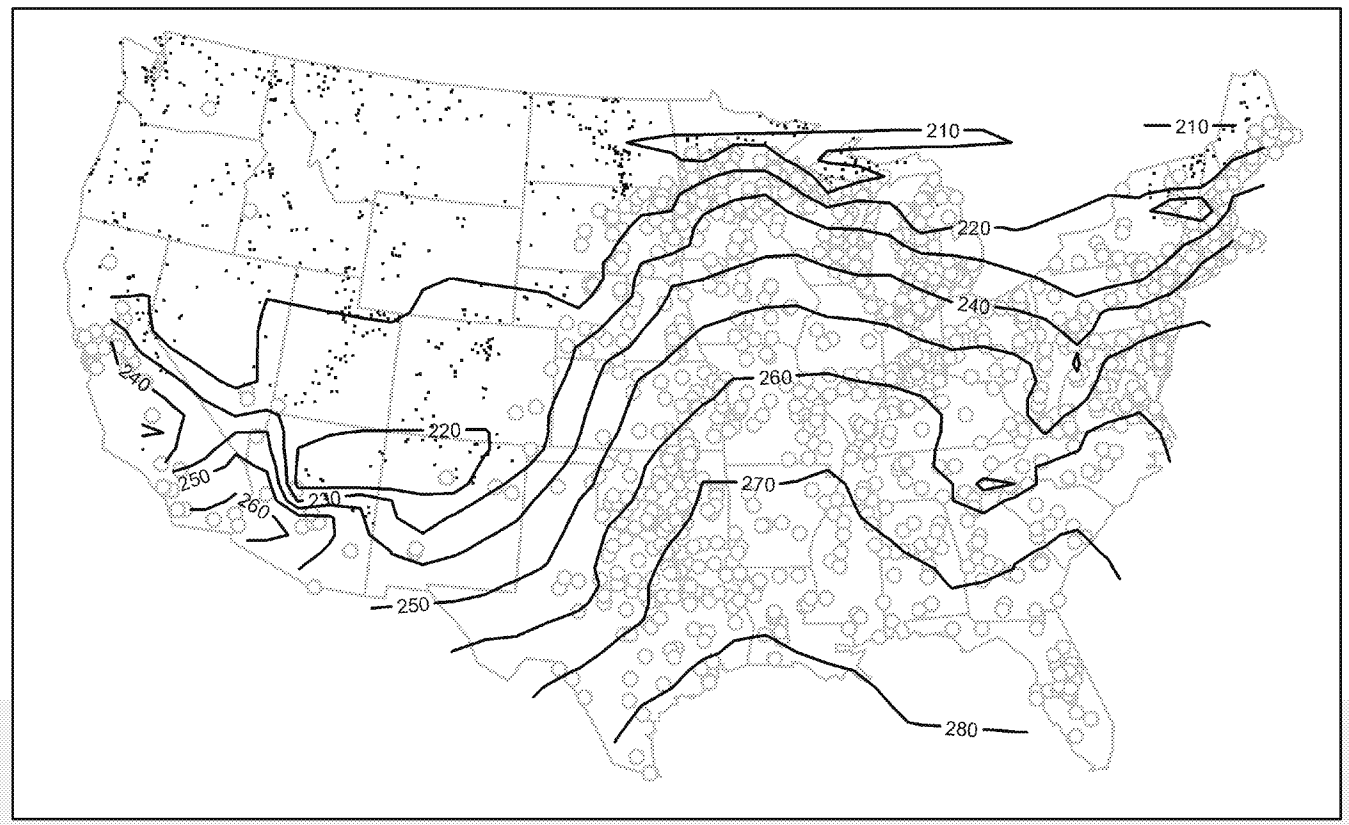
Lake surface temperature



We can predict the average day of the year that surface lake decreases below different temperature limits (predictions for 24° shown).

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Aquatic life assessment endpoints: Summary

- Zooplankton endpoint can apply to all lakes.
- Fish/dissolved oxygen endpoint can apply to lakes that stratify seasonally and that harbor cool-water fish.

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Defining assessment endpoints to protect drinking water source

- Management goal:
  - State designated use related to protection of public water supplies

- Assessment endpoints: "…explicit expressions of the actual environmental value that is to be protected…"

- Endpoint ensures that drinking water source water are protected from microcystin, the most commonly occurring algal toxin. Focus on consumption by children.
  - US EPA Health Advisory

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Defining assessment endpoints to protect recreational waters

- Management goal:
  - State designated use related to allowing recreational activities in or on the water

- Assessment endpoints: "…explicit expressions of the actual environmental value that is to be protected…"

- Endpoint ensures that children swimming in recreational waters are protected from microcystin, the most commonly occurring algal toxin.
  - Criteria recommendation/swimming advisory values for microcystins.

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Assessment endpoints: Summary

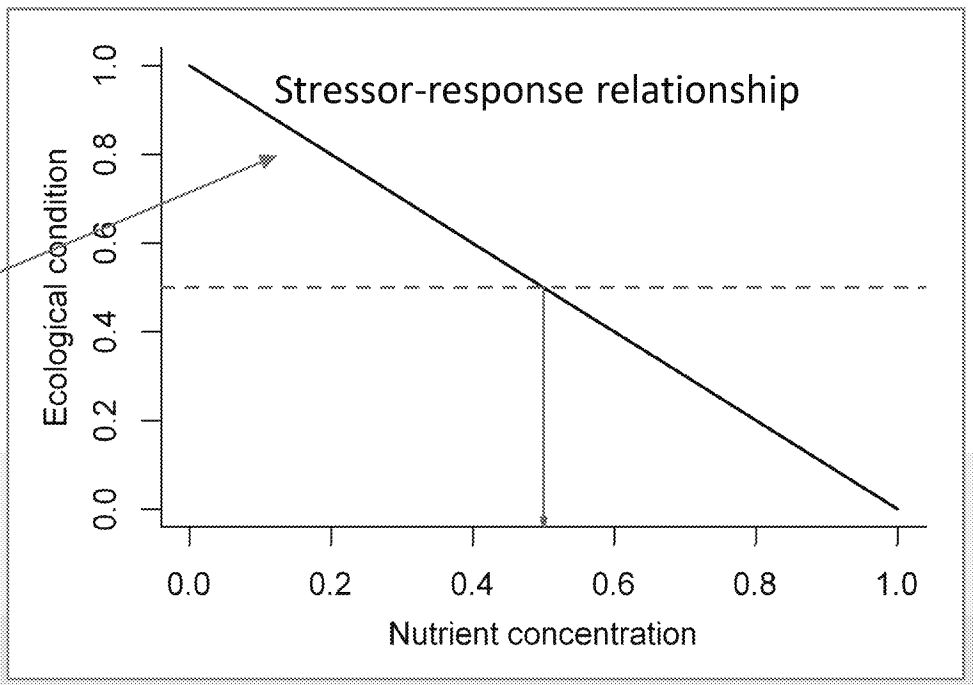
- Characteristics of useful assessment endpoints:
  - Responsive to nutrients
  - Quantitative
  - Linked directly to management goal
  - Data available

- National scale of 304(a) recommended criteria limited by data availability
  - Additional endpoints one might consider at local scales:
    - Fish abundance
    - Diatom composition
    - Water transparency

Stressor-response analysis Step 2:

Derive the stressor-response relationship.

How do we derive the position and shape of this line?



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Approach

- Model known causal relationships.
  - Model proximal relationships when possible.
- Use functional forms that are consistent with underlying mechanisms.
- Model relationships among groups of measurements with Bayesian networks.

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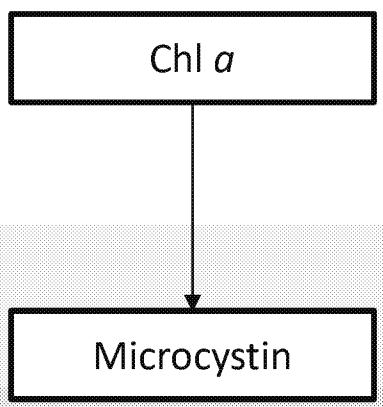
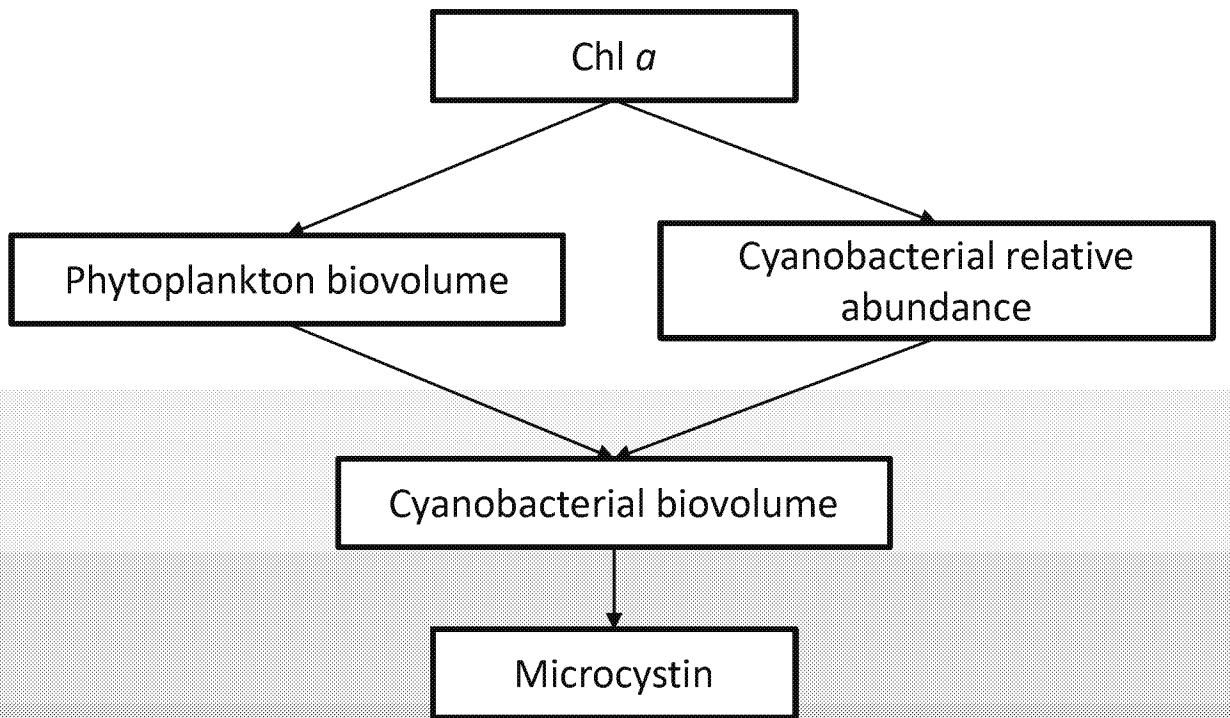
Stressor-response relationships

Modeling a network of relationships allows us to specify relationships between pairs of variables that better represent underlying mechanism.





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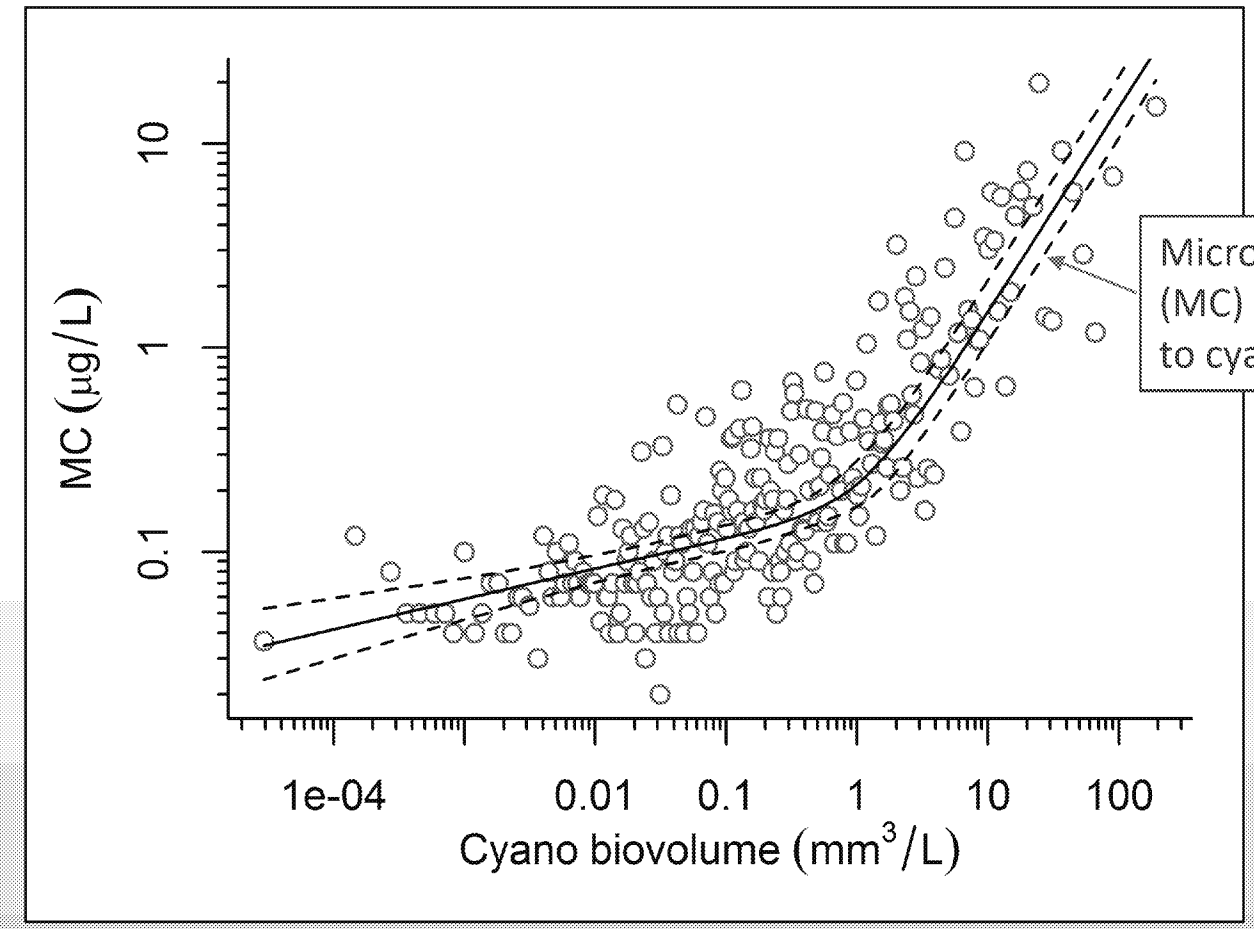
Cyanobacterial biovolume and microcystin



Microcystin concentration (MC) is directly proportional to cyanobacteria biovolume.

Revised phosphorus-chlorophyll models

Model equation:

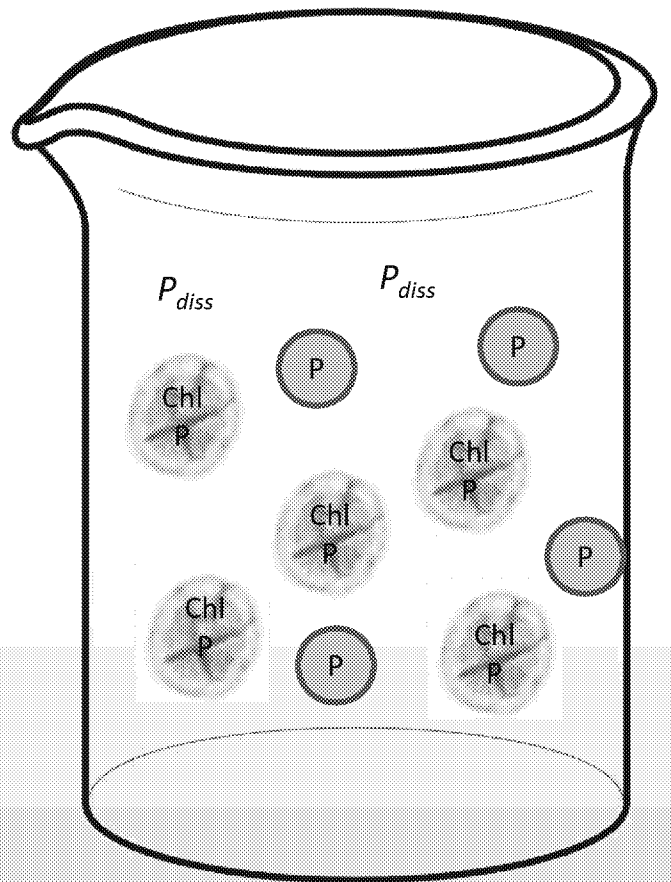
$$TP = d_1 Chl^k + d_2 Sed + P_{diss}$$

When sediment and P_{diss} concentrations are low, we can simplify to the following:

$$TP = d_1 Chl^k$$

$$\log(TP) = \log(d_1) + k\ log(Chl)$$

Lower bound between log(TP) and log(Chl) should be a straight line.



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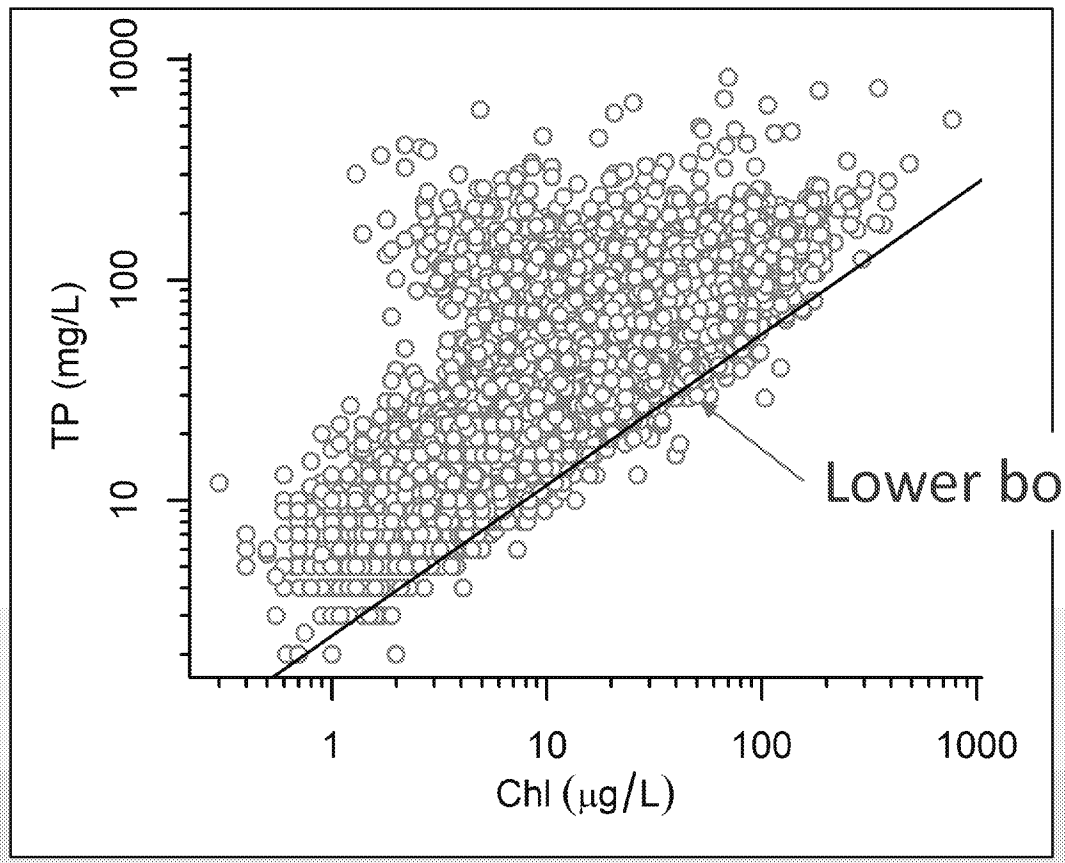
Data from MO reservoirs



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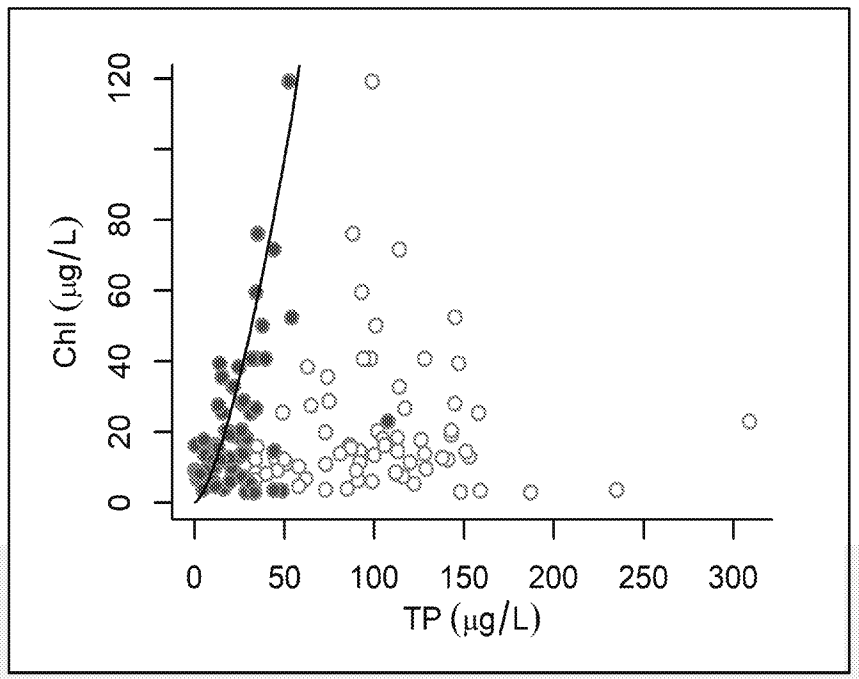
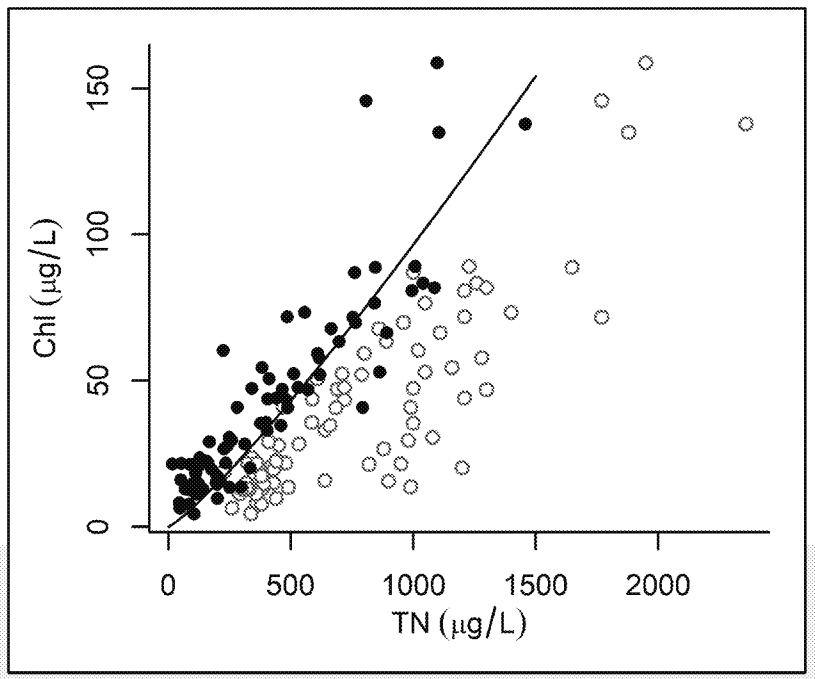
Relationships between total phosphorus, total nitrogen, and chl *a*





Controlling for the effects of phosphorus bound to sediment and dissolved organic nitrogen greatly improves the precision of TP-Chl *a* and TN-Chl *a* relationships.

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Stressor-response: Summary

- Chl *a* criteria can be derived for three designated uses.
  - Drinking water and recreation: Chl *a* – microcystin model
  - Aquatic life:
    - Chl *a* – zooplankton model
    - Chl *a* – fish/hypoxia model
- TN and TP criteria can be derived from models linking nitrogen, phosphorus, and chl *a.*

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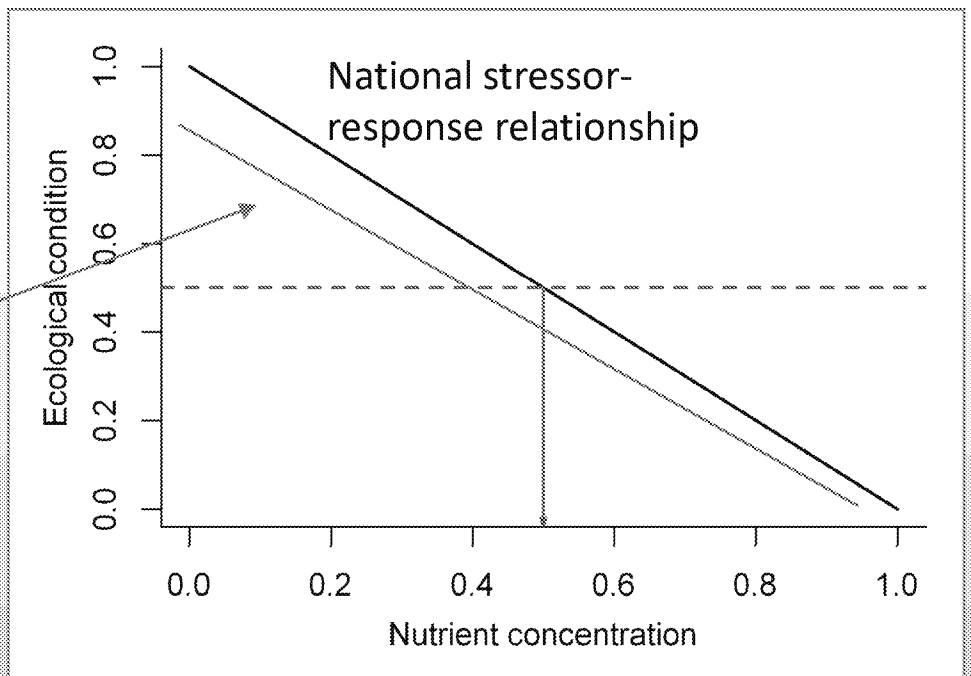
Provides tools that combine state and national data

- We have been working in partnership with states who volunteered to pilot test our tools for combining their state data with national models.
- Analysis results can be used to derive locally-applicable criteria.

State data can reflect local conditions that can differ from national average.



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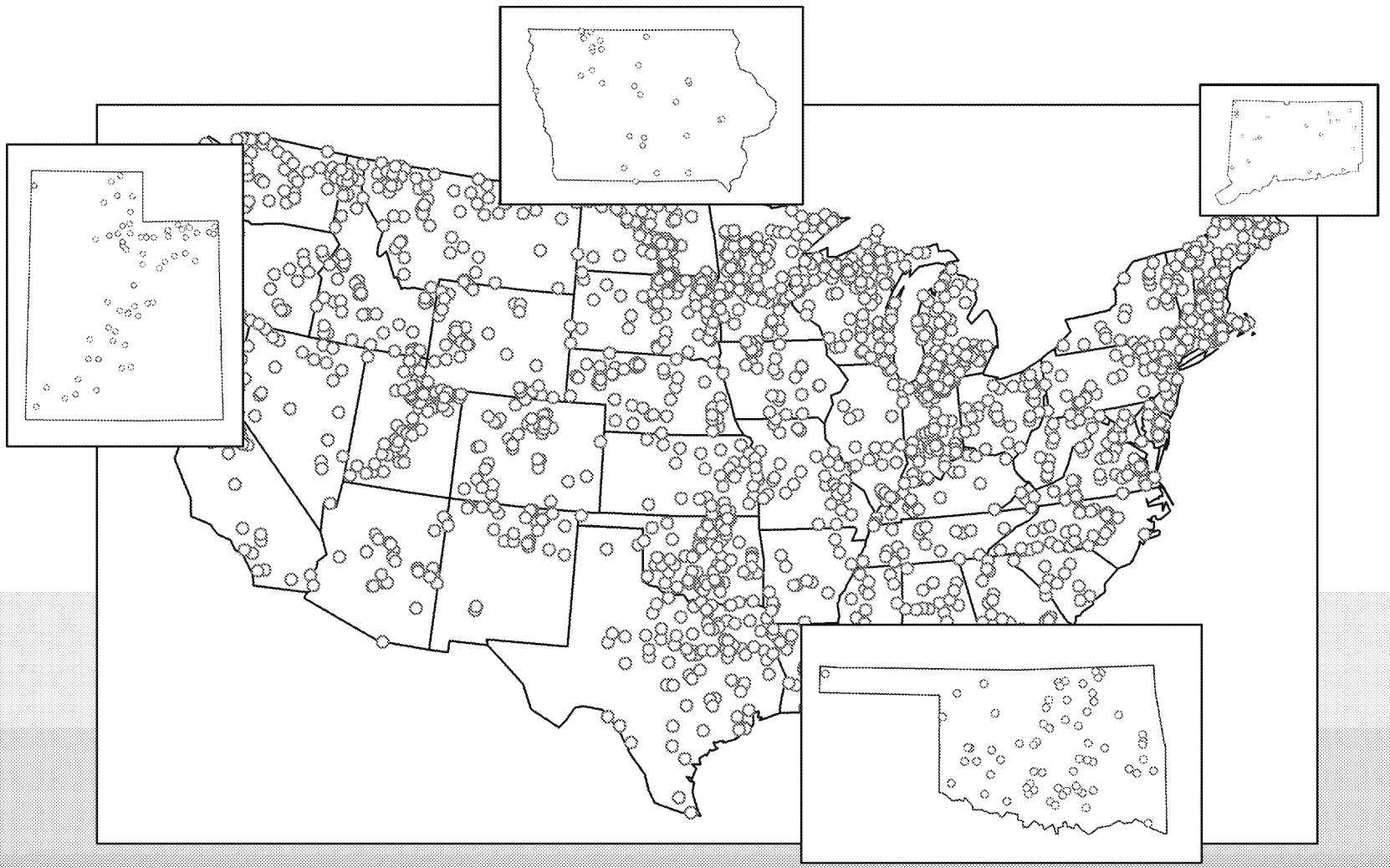
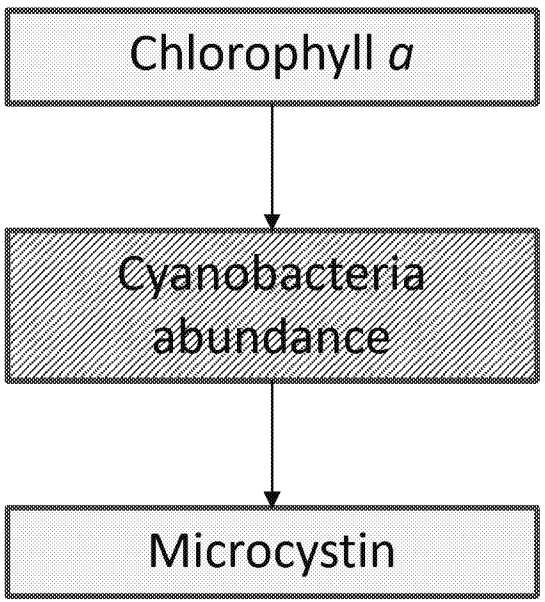
State-specific Models



Example: Iowa case study

- Chl *a* and microcystin data were available in Iowa.
- National and Iowa data were used to develop a chl *a* - MC relationship.
- The national model sets a range for possible relationships in IA, and "fills in" for missing measurements.



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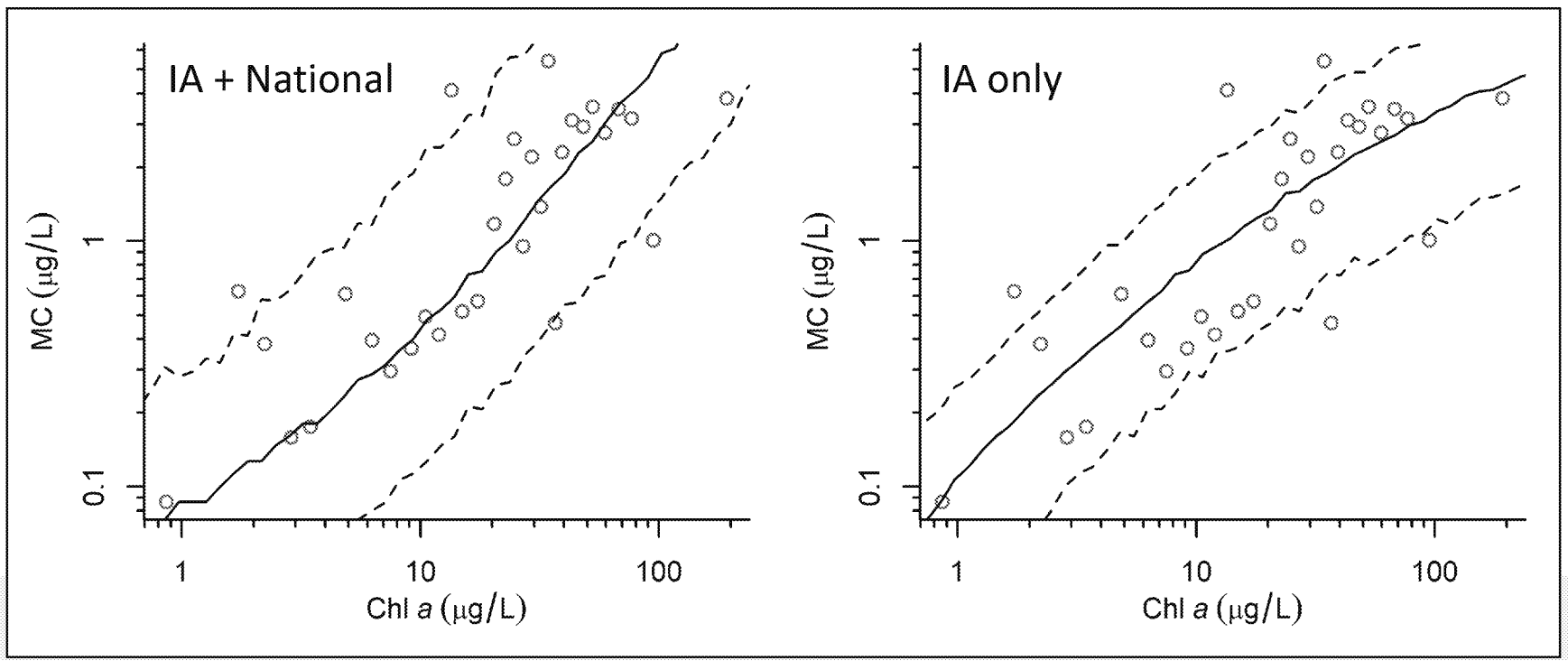
Iowa case study



Combining IA data with national models yields a 13% improvement in model precision.

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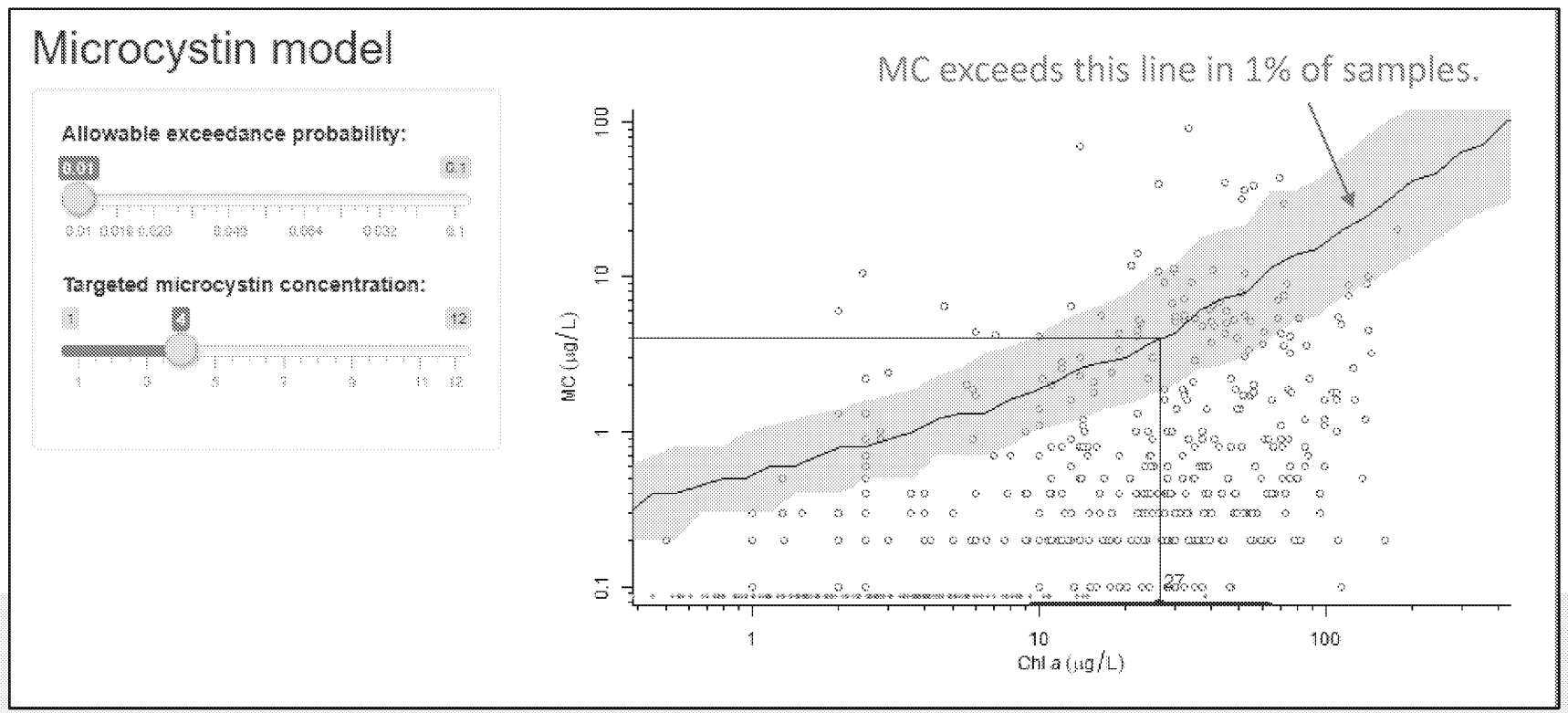
Iowa case study



Graphical interface allows state staff to set risk management decisions (e.g., allowable exceedance probability) and derive state-specific criteria.

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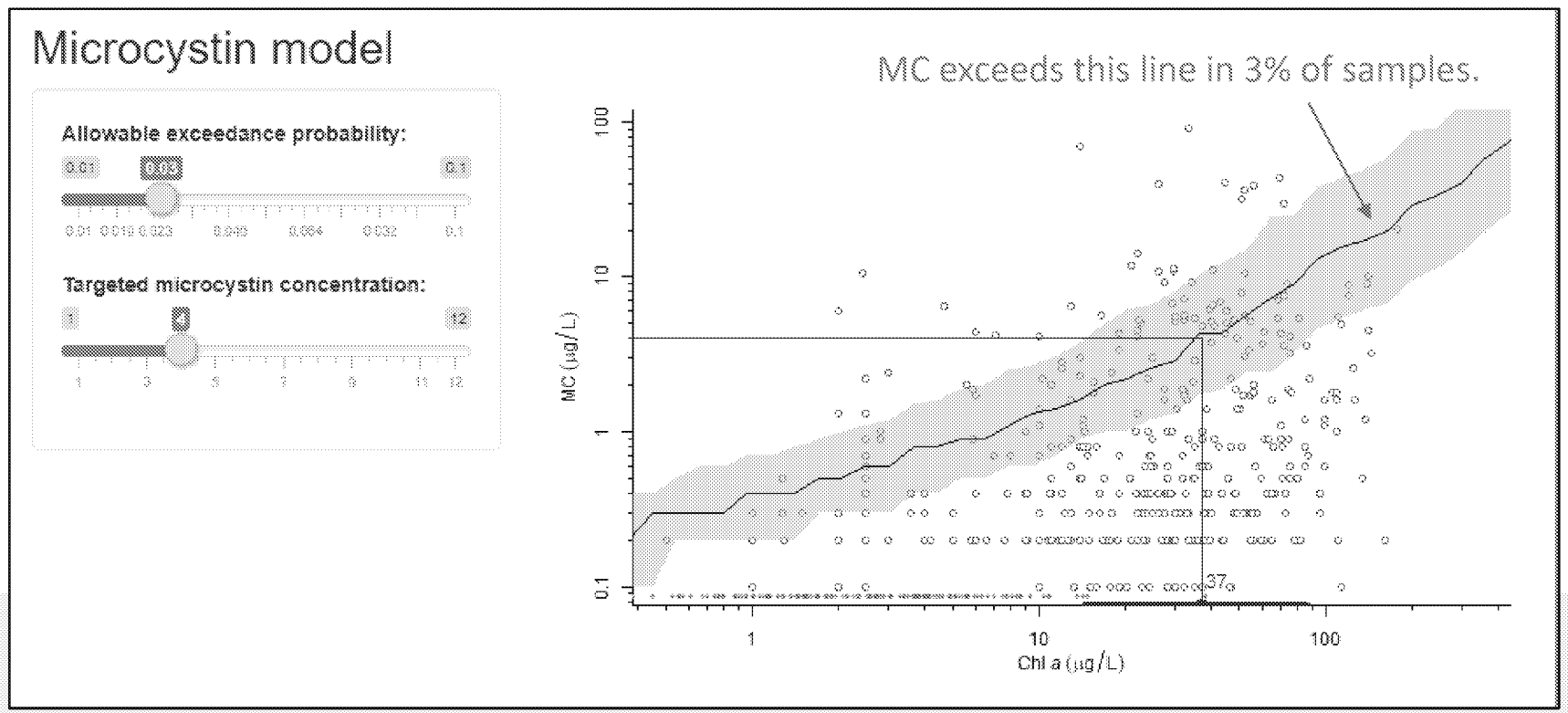
Iowa case study



Graphical interface allows state staff to set risk management decisions (e.g., allowable exceedance probability) and derive state-specific criteria.

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Next Steps

- Early 2020: Publish draft criteria.
- 60 day public comment period.